EXTENDING THE CLEAN DEVELOPMENT MECHANISM CONCEPT TO BUILDING PROJECTS

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The Clean Development Mechanism (CDM) is a global scheme intended to provide a flexible way to comply with carbon emissions reduction commitments through emissions trading. In this scheme, countries can purchase certified emission reduction (CER) credits, each equivalent to one tonne of avoided emissions, to meet part of their emission reduction commitments. The CER credits are generated from emission reduction activities that are undertaken in developing countries. Although the CDM has benefited several sectors, the building sector hitherto accounts for a meagre proportion of the globally registered CDM initiatives. However, recent research suggests that there is potential in using the CDM concept to address carbon emissions associated with buildings. Further to this suggestion, this paper presents a demonstration of how the CDM concept could be applied to building projects in a developing country, Uganda. A two-bedroom residential house was considered as the unit of analysis and carbon emissions associated with constructing its walls were derived, considering materials, plant, and workforce used. Two options for the house were considered: a baseline (i.e. constructed using typical materials, plant, and labour) and green alternative (i.e. constructed using provisions to reduce carbon emissions). The difference in carbon emissions in the two options was found to constitute a basis for a CDM whose structure is presented and discussed in this paper. Considering a bottom-up projection regarding construction of residential houses in Uganda, the findings show that using the CDM concept, carbon emissions reduction of over 200 $ktCO_2$ could be achieved in a period of 10 years. These figures were found comparable with prevailing CDM initiatives which are not associated with buildings. The overall findings indicated that extending the CDM concept to building projects is plausible and could promote market-based mechanisms of enhancing sustainable construction.

Keywords: carbon emissions, clean development mechanism, sustainable construction.

INTRODUCTION

The intervention of national and international emissions reduction regulatory regimes suggests that global warming is recognised as a global threat (UK Climate Change Act 2008; WRI/WBCSD 2005; Kyoto Protocol 1998; UNFCCC 1992). Global warming is primarily caused by increasing concentrations of greenhouse gases (e.g. carbon dioxide, methane, nitrous oxide, etc.) in the atmosphere, most of which arise from human activities such as burning of fossil fuels and manufacture of materials like cement (Hegerl *et al*. 2007; Worrell *et al*. 2001). For such a global threat, attempts to address it have, ipso facto, taken the form of global initiatives. One of such acclaimed

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global initiatives is the Clean Development Mechanism (CDM), which, although has appealed to several sectors, its popularity in the building sector is hitherto dismal.

The principle and aims of the CDM concept are quite straight forward. CDMs were established under Article 12 of the Kyoto Protocol (1998) – an international treaty to reduce greenhouse gas (GHG) emissions– to provide flexible market-based mechanisms of reducing GHGs by emissions trading. For industrialised countries that are signatory to the Kyoto Protocol (1998), they had to reduce their emissions by 5% of 1990 levels during the first commitment period of 2008 to 2012. The second commitment period, as adopted in the 'Doha amendment to the Kyoto protocol', stipulated another 8-year commitment period (2013 to 2020) to reduce emissions by 18% below those of 1990 (UNFCCC 2013a). In CDM initiatives, industrialised countries with emission-reduction commitments can purchase certified emissions reduction (CER) credits, each equivalent to one tonne of emissions avoided. The purchased CER credits can then be used to offset emission reduction targets. However, the CER credits must have been generated from emission-reduction activities (e.g. planting of trees, renewable energy projects, energy efficiency measures etc.) undertaken in developing countries. Thus developing countries benefit from the revenue resulting from the sale of CER credits, and other benefits such as employment, that the emission-reduction activity can accrue. So, the aim of CDM is dual: enabling industrialised countries to meet emission reduction targets, while facilitating developing countries to achieve sustainable development (Kyoto Protocol 1998).

Although buildings are both energy and carbon-intensive, they have not yet attracted adequate attention from CDMs. The building sector globally consumes up to 40% of the final energy and releases 30% of the annual global emissions (WBCSD 2012; UNEP 2009). If the energy consumed during the construction phase is considered, buildings account for more than 50% of the global energy consumption (WBCSD 2012). However, by February 2006, nearly a year after the CDM concept came into force, less than 5% of the total registered CDMs were related to buildings, with none in pipeline for registration (Novikova *et al*. 2006). By May 2008, of the 3000 CDMs in pipeline then, only six were related to buildings (Cheng *et al*. 2008). Even in countries like China, which host the largest share of CDMs globally, the building sector is still not a popular attraction for CDMs (Zhou *et al*. 2013). Moreover, for the few registered building-related CDMs, they are related to the operation phase of buildings and none addresses the construction phase of buildings. Unsurprisingly, current information available from the CDM repository shows that, for the designated fifteen CDM sectoral scopes, there are currently no registered CDMs under the 'Construction sector' scope (UNFCCC 2015). As such, the mystery surrounding the paucity of building-related CDMs indeed deserves investigation.

Recent research has endeavoured to explore various aspects pertaining to CDM activities related to buildings. In most of the cases (UNEP 2009; Cheng *et al*. 2008; Hinostroza *et al*. 2007; Novikova *et al*. 2006) discussions have dwelt on underscoring the barriers hindering buildings to benefit from CDM; these include: transaction costs outweigh economic benefits, buildings are small-scale in nature, buildings are both fragmented and geographically spread, lack of appropriate methodologies, and lack of reference baselines. Some researchers (see Mok *et al*. 2014; Zhou *et al*. 2013) have taken a step further to conduct empirical research with the objectives of, among others, suggesting potential solutions to such barriers. Meanwhile, other studies (e.g. Kibwami and Tutesigensi 2014a) claim that CDMs could promote sustainable construction in developing countries. However, there are no studies that provide a demonstration of how the CDM concept can be applied to buildings and more so, elucidate how building-related CDMs could promote sustainable construction. To fill this gap, this paper presents a demonstration of how the CDM concept can be applied to building projects in the context of Uganda.

Since CDMs must be hosted by developing countries (Kyoto Protocol 1998, Paragraph 3a), it is reasonable to consider the CDM concept in the context of Uganda. Uganda is a developing country (UNCTAD 2011) that has hosted several CDM initiatives (Olsen 2006), and it was the first in Africa to undertake a forestry CDM project (World Bank 2009). However, the global scarcity of CDMs in the building sector also reflects on Uganda, as the country has no CDMs related to the building sector. Yet, the country's efforts of increasing the rate of housing construction (Kalema and Kayiira 2008) in order to counter the persistent housing deficit (The New Vision 2008) affects the environment. It is widely acknowledged that construction is associated with activities (material manufacture, transportation, equipment use and so forth) that lead to carbon emissions (UNEP 2009; Cole 1998). Therefore, if a developing country like Uganda is to pursue a low-carbon path to development, which in this case implies shrinking the housing deficit sustainably, consideration of CDMs related to buildings is important.

METHODOLOGY

In order to demonstrate how the CDM concept can be applied to building projects, some considerations were made upon which emissions calculations were based.

Considerations

A typical dwelling unit (see Table 1), whose details were obtained from an engineering firm, was assumed to be constructed in Kampala, the capital city. A model suggested in Kibwami and Tutesigensi (2014b) was used as guidance in computing the resulting carbon emissions. Two options of constructing the dwelling's walls were considered: a baseline constructed using typical materials, plant/equipment, and workforce; and a 'green' alternative constructed using provisions to reduce carbon emissions. Thus for the entire dwelling unit, potential emission reductions were associated with construction of its walls only, similar to recent proposals by UNFCCC (2013b). Energy sources were diesel, biomass, heavy fuel oil, biodiesel, and grid electricity, since these are either predominantly used, or have a great potential (UBOS 2013). The emission-factors (see Table 2) were taken from UNFCCC (2010) which is a country-related source and thus considered to be representative of the context. The disaggregation factors referred to in the referenced model were taken as the various proportions of energy required for the baseline and alternative options (see Table 3). The proportions for the baseline option were based on typical energy use in Uganda. For instance, energy used in the cement industry comes from diesel, biomass, heavy fuel oil, and grid electricity; in some factories, biomass accounts for 30% of the total energy used (Lafarge 2012). The alternative option was based on the goal of Uganda's renewable energy policy: dependence on 61% renewable energy by 2017, with biofuel blends of up to 20% in the transport sector (The Republic of Uganda 2007). Therefore, for manufacture of materials in the alternative option, 60% of the energy was assumed to be sourced from non-fossil renewable energy, whereas 20% biofuel blend was assumed in all transportation activities. The overall emissions computed arose from manufacture and transportation of materials, and transportation of workforce. Emissions from equipment-use were not considered since the activity of constructing the walls was assumed to be entirely carried out by human workforce without need for powered equipment.

Table 1: Information about the house

Parameter	Description
Building type	Typical two-bedroom residential house
Construction type	Traditional: masonry burnt mud bricks
Floor to wall-plate height	3m
Number of bedrooms	2No.
Number of floors	1No.
Internal floor area	103m2
Total wall area	223m2
Wall width (un-plastered)	0.107m (based on 228x 107 x 69mm bricks)*
Openings areas: Doors	21m2
Windows	24m2
Roof type and structure	Corrugated iron sheets on Timber roof truss structure
Total Cement required (walling only)	2.23Tons (assuming 0.01tons per m2, stretcher bond)*
Total bricks required (walling only)	11,147 bricks (50 bricks per m2)
Total sand required (walling only)	1 trip, 6-tonne truck
Water	excluded in the analysis

**source: UNFCCC (2013b)*

Table 2: Emission factors for common energy sources in the context

Fuel/energy source	Emissions factor*	Conversion to MJ 1kWh=3.6MJ
Diesel (100% mineral diesel) for vehicles	0.545 kgCO2/km	N/A
Diesel (electricity)	0.68 KgCO2/kWh	0.189 KgCO2/MJ
Heavy fuel oil (HFO) for electricity	0.71 KgCO2/kWh	0.197 KgCO2/MJ
Biomass	0	N/A
Grid electricity (diesel, HFO, and Hydroelectricity mix)	0.14 kgCO2/kWh	0.039 KgCO2/MJ

source: UNFCCC (2010)

Table 3: Proportion of energy used

Energy sources	Material (cement) manufacture		Transportation (material or workforce)	
	Base line	Alternative	Base line	Alternative
Diesel	0.35	0.10	1.00	0.80
Non-fossil	0.30	0.60	0.00	0.20
Heavy fuel oil	0.05	0.00	N/A	N/A
Electricity	0.30	0.30	N/A	N/A
Total	1.00	1.00	1.00	1.00

Assumptions regarding emissions from manufacture (and transportation) of materials, and transportation of workforce were posed. For cement manufacture, which causes both energy (46%) and process-related (54%) emissions, the energy requirement was taken as 4.9MJ/kg (Worrell *et al*. 2001: 321). The country's two largest cement producers 'Hima' (in the West) and 'Tororo' (in the East) are located approximately 350 km and 209 km respectively from the capital city (based on Google Maps); a 560 km average roundtrip was considered, based on a 6-ton diesel truck (UNFCCC 2010). According to typical brick manufacturing practices in Uganda (i.e. wood-fired kilns), the associated emissions were cautiously taken as zero, similar to Pooliyadda and Dias (2005). Also, no production emissions were considered for sand, as it is a naturally occurring material that is usually unprocessed, though requires transportation. Bricks and sand are usually sourced not very far from construction sites; a 50 km roundtrip distance was considered in each case, based on a 6-ton diesel truck. For emissions from transportation of workforce, a typical 14-passenger public transportation vehicle was considered. Similar to Cole (1998), no vehicle-sharing was assumed and thus each person travelled separately. Emissions per person per unit distance were obtained as: 0.545kgCO_2/km ÷ 14 = 0.0390kgCO_2. Each person was assumed to travel a 20 km roundtrip per-day and thus emissions per person per day were: 0.039 × 20 = 0.780 kgCO_2. A total workforce of four people was presumed: two masons, each with an assistant. Since a mason can construct 3.17 m^2/day (Nalumansi and Mwesigye 2011), yet 223m^2 of walls were to be constructed, the total construction duration was obtained as: 223m^2 ÷ 3.17m^2/day ÷ 2 = 35 days.

Calculation process

Emissions from manufacture of materials were computed by multiplying the total energy required to manufacture a unit of material, with the proportion of energy source used (see Table 3), with the emission factor of that energy source (see Table 2), and with the total quantity of material required (see Table 1). For instance, considering diesel-emissions in manufacturing cement, the baseline and alternative options were computed as: 4.9MJ/Kg × 0.35 × 0.189 kgCO_2/MJ × 2230Kg = 722 kgCO_2 and 4.9MJ/Kg × 0.10 × 0.189 kgCO_2/MJ×2230kg = 207 kgCO_2, respectively (see Table 4). This calculation process was repeated for other energy sources, but with varying proportions (as per Table 3) of energy sources used.

Emissions from transporting materials were computed by multiplying the distance of transporting materials, with the proportion of energy source used, with the emissions emitted per unit distance for that energy source. Taking an example of transporting cement, the baseline and alternative options were computed as: 560 km × 1.00 × 0.545 kgCO_2/km = 305 kgCO_2 and 560 km × 0.80 × 0.545 kgCO_2/km = 244 kgCO_2, respectively (see Table 4). A similar calculation was applied for bricks and sand.

Emissions from transporting workforce were computed by multiplying the emissions per person per day, with the proportion of energy source used, with the total workforce required for the activity, with the total duration of the activity. Thus the baseline and alternative options were computed as: 0.780 kgCO_2/person/day × 1.00 × 4 people × 35 days = 110 kgCO_2 and 0.780 kgCO_2/person/day × 0.80 × 4 people × 35 days = 88 kgCO_2, respectively (see Table 4).

RESULTS AND DISCUSSIONS

Total emissions were considered based on the baseline and alternative scenarios. The implication of the results in relation to CDM was then discussed, followed by a presentation and discussion of the structure for the suggested CDM.

Amount of carbon emissions

The total emissions for the baseline and alternative options were 2550 kgCO_2 and 1834 kgCO_2 respectively (see Table 4), as further elaborated below.

Baseline

The total emissions for the baseline option represented 11 kgCO_2/m^2 of wall. With respect to manufacture, diesel contributed the most (75%) energy-related emissions. The amount of emissions was highly sensitive to heavy fuel oil, as it had the largest emission factor (0.71 kgCO_2/kWh) amongst the fuels considered. Transportation emissions (including materials and workforce) were 18% of the total emissions, implying that at 82%, the manufacture of materials contributed the most emissions. Such findings were not surprising since materials are known to constitute the biggest proportion of buildings' 'embodied' emissions (Chang *et al*. 2012: 794; Nässén *et al*. 2007: 1599; Scheuer *et al*. 2003: 1057).

Alternative

For the alternative option, the total emissions translated into 8 kg $kgCO_2/m^2$ of wall. This represented a reduction of 27% from the baseline option. The total energy-related emissions for manufacturing materials reduced from 957 $kgCO_2$ to 334 $kgCO_2$, representing a reduction of 65%. Workforce and material transportation emissions reduced by 20%. The alternative option therefore demonstrates how a certain construction practice can deviate from the baseline practices (e.g. by sourcing materials from manufacturers who use renewable energy, using biofuels in transporting materials and/or workforce, etc.) in order to reduce emissions. Such deeds demonstrate principles of attaining sustainable construction (Hill and Bowen 1997).

Table 4: Emissions from baseline and alternative options

		Baseline (kgCO2)	Alternative (kgCO2)
Manufacture of materials	Diesel	722	207
	Non-fossil	0	0
	Heavy Fuel Oil	108	0
	Electricity	127	127
	Non-fuel related emissions (54%)	1124	1124
	Subtotal	2081	1458
Transportation of materials	Cement	305	244
	Bricks	27	22
	Sand	27	22
	Subtotal	359	288
Transportation of workforce	Diesel-vehicle	110	88
Grand total		2550	1834

Implications of the results in relation to CDM

To address housing shortage in the capital city of Uganda, over 28,000 housing units have to be constructed annually within a duration of 10 years (UN-HABITAT 2010: 37). Assuming similar house units, for 2550 $kgCO_2$ per house, constructing walls of 28,000 houses would result into baseline emissions of 71 $ktCO_2$ (i.e. 2550 × 28000) annually. However, for the alternative 'greener' scenario, the annual emissions would be 51 $ktCO_2$ (i.e. 1834 × 28000), resulting in emission reductions of 20 $ktCO_2$ annually. If a duration of 10 years is considered, a total of 200 $ktCO_2$ would be avoided. These figures are comparable to those of CDMs that are not related to the building sector (see Table 6). Therefore, creating a CDM related to building projects (BP-CDM) is feasible, and considering the prevailing CDM modalities, it would be classified under small-scale CDM types which have emission reductions of up to 60 kt per year (UNFCCC 2014: 40). However, as demonstrated, the initiative would require covering a substantial geographical part of the country whereby in this case, the whole capital city would be considered as a single CDM project.

Table 5: Some registered CDMs in Uganda and extent of emission reduction

No.	Project title and registration date	Total reductions (tCO2eq)	Annual Reductions (tCO2eq)	Operation period (years)	Sector*
1	West Nile Electrification Project (WNEP); 10th February 2007	760,417	36,210	21	E/R
2	Uganda Nile Basin Reforestation Project No.3; 21st August 2009	111,798	5,564	20	A/R
3	Bugoye 13.0 MW Run-of-River Hydropower Project; 1st January 2011	510,740	51,074	10	E/R
4	Kachung Forest Project: Afforestation on Degraded Lands; 4th April 2011	547,373	24,702	20	A/R
5	Uganda Nile Basin Reforestation Project No. 4; 29th August 2011	79,395	3,969	20	A/R
6	Bujagali Hydropower Project; 7th October 2011	6,007,211	858,173	7	E/R
7	Mpererwe Landfill Gas Project; 20th January 2012	182,612	18,261	10	W/D
8	Buseruka Mini Hydro Power Plant; 21st May 2012	314,679	31,468	10	E/R
9	Namwasa Central Forest Reserve Reforestation Initiative; 31st January 2013	226,564	11,328	20	A/R

**E/R - Energy industries Renewable/non-renewable, A/R - Afforestation and Reforestation, W/D - Waste handling and Disposal, BP - Building Project. Source: (UNFCCC 2015)*

Structure of the suggested CDM

Since building projects are usually geographically spread, a Programme of Activities (PoA) type of CDM would be appropriate. In PoA CDMs, several projects sharing similar goals can be registered as a single CDM (UNFCCC 2014). Since the project sites in a PoA can be located in various parts of a country (Fenhann and Hinostroza 2011), this can similarly relate to building projects. To manage the geographical spread of building projects, existing local government administrative authorities such as districts, can be used. Each district would be taken as a Component Project Activity (CPA) of the PoA. A CPA is technically defined as *"a single measure, or a set of interrelated measures under a PoA, to reduce emissions or result in net removals, applied within a designated area."* (UNFCCC 2014: 22). In operationalising the BP-CDM, the CPAs would keep up-to-date official records (e.g. of emission factors) specific to the geographical region concerned. Upon building permit applications, baseline emissions would be assessed. The investors (e.g. clients, contractors) who opt in for the BP-CDM can then be advised of 'greener' options such as which manufacturers to buy materials from. On completing construction, a reassessment could be done, and the extent of deviations from the baseline revealed. If positive (i.e. emissions reduced), a verification can be carried out to assess where the emission reductions were achieved (e.g. whether manufacturer, contractor, client or workforce) in order to apportion incentives appropriately. The BP-CDM can be structured into three levels (see Figure 1), each with various actors and responsibilities.

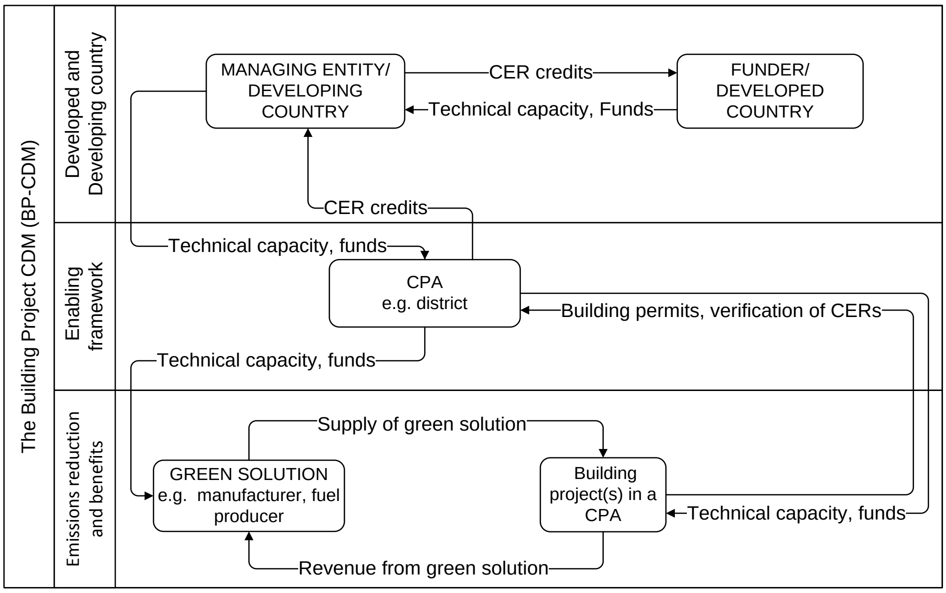

Figure 1: Suggested structure of the CDM related to buildings

In the top level, the developed country offers technical capacity and funds to implement a 'green' solution and in return, receives CERs from the developing country. Technical capacity and funds are extended to the CPAs (see middle level of the diagram) which also extend the same to the implementers of the green solution, who might be manufacturers or building projects. When manufacturers supply 'green' materials to the building project, they receive revenue. If manufacturers have obtained funds from the CPAs in order to manufacture ‘green’ materials, they can be tasked to offer the materials at lower competitive prices. But, if manufacturers do not claim funds from CPAs, and therefore sell materials at premium prices, the building projects could then redeem the premium from the CPAs. With such incentives, manufacturers can be tasked to be more innovative in search for greener solutions since the demand will be available. For building projects, this could prompt stakeholders to adopt practices that are less carbon intensive. In so doing, the BP-CDM could translate into a market-based mechanism of promoting practices that enhance sustainable construction, whilst advancing the goals of renewable energy policy.

CONCLUSIONS

According to available records, there is currently no registered CDM related to buildings with regard to the construction scope, yet recent studies underscore the potential of building-related CDMs. In response, this work has demonstrated that CDMs can be applied to construction of buildings with a case of housing in Uganda. Through a bottom-up analysis, it was revealed that, within the capital city alone, 20 $ktCO_2$ of emissions could be avoided annually via a CDM initiative. Since promotion of sustainable development is one of the CDM’s objectives, if suggestions in this work are adopted, construction processes in Uganda and other developing countries can contribute to sustainable construction and also support renewable energy policy. However, there were some limitations, such as paucity of data, which are inherent of research in a developing country. For instance, there were no country-specific databases on energy use and emissions. As such, absolute figures presented should not be simplistically interpreted as accurate representation of the cases and the context but rather, a guidance to conceptualise the assertions made. This work focussed on construction of walls only but there would be greater potential if the 'whole building' was considered. This being an exploratory study, more studies that consider more aspects of the building fabric are necessary to corroborate these findings. In furthering the contribution made by this work, there is need to engage various CDM and built environment stakeholders such as funders (e.g. World Bank), managing entities (e.g. ministries), local authorities, manufacturers, and built environment professionals in order to assess the feasibility of practically implementing the suggested CDM initiative. This is a potential area for further research.

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